

# Investigation of the Electrification of Pyrocumulus Clouds

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Additional Acknowledgements: DOE Py-ART Software Team, Wikimedia Commons

## Outline of Talk

**1. Background and Motivation**

**2. 2013-2014 Pyrocumulus Lightning Cases**

**3. Geostationary Lightning Mapper (GLM) Proxy Data**

**4. Summary and Conclusions**

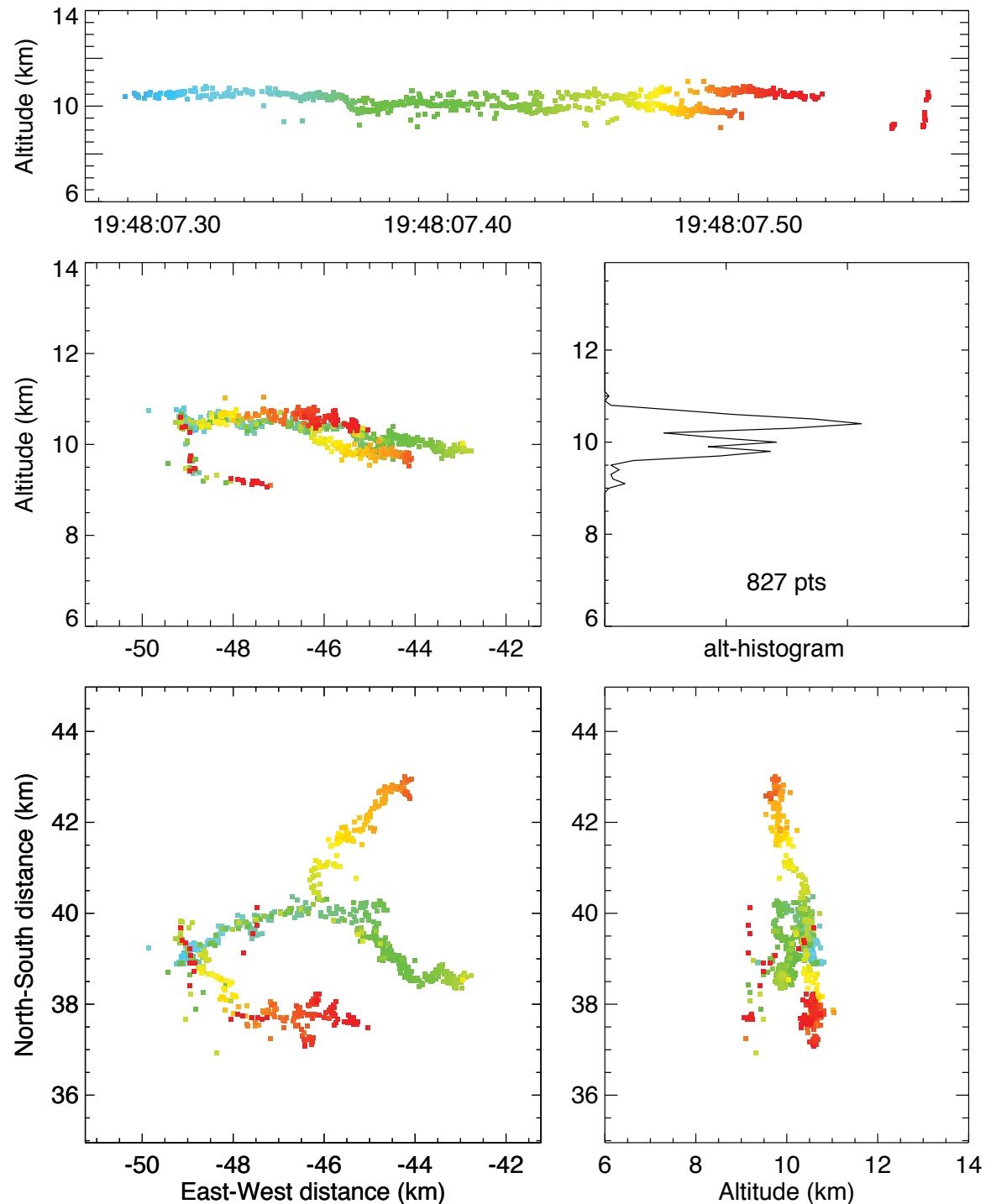
# Background

## Typical Pyrocumulus Lightning Flash

(Lang et al. 2014)

Hewlett Fire flash detected by Colorado Lightning Mapping Array (COLMA)

- Intracloud (not CG)
- High-altitude (~10 km MSL)
- Shallow (~2 km deep)
- Duration  $\ll 1$  s
- Small!  $L \sim 5$ -7 km
- Positive charge overlaying negative (“normal” polarity)
- Numerous precursor VHF sources starting ~30 s prior to flash



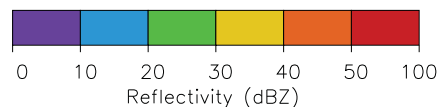
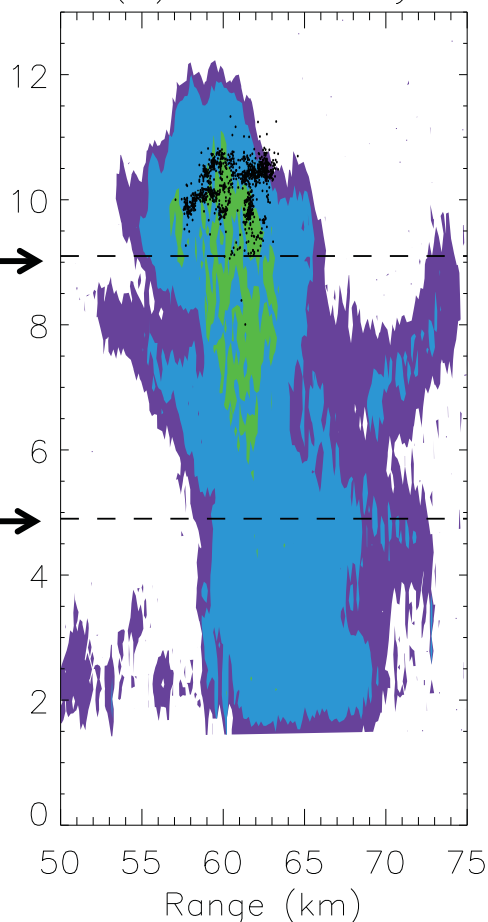
CHILL RHI  
(1949 UTC)  
LMA Flash  
(1948 UTC)

-40 °C

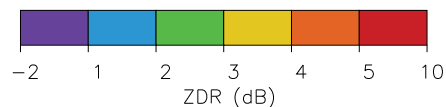
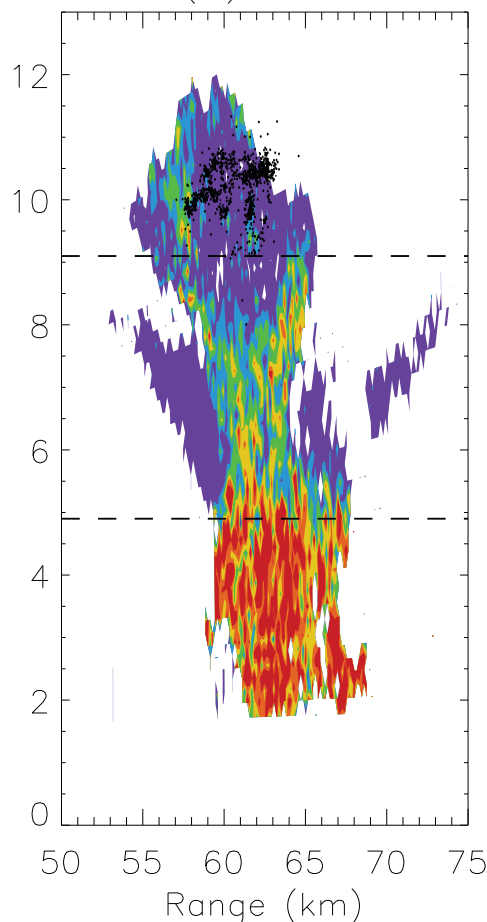
LCL

Height (km MSL)

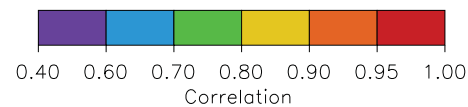
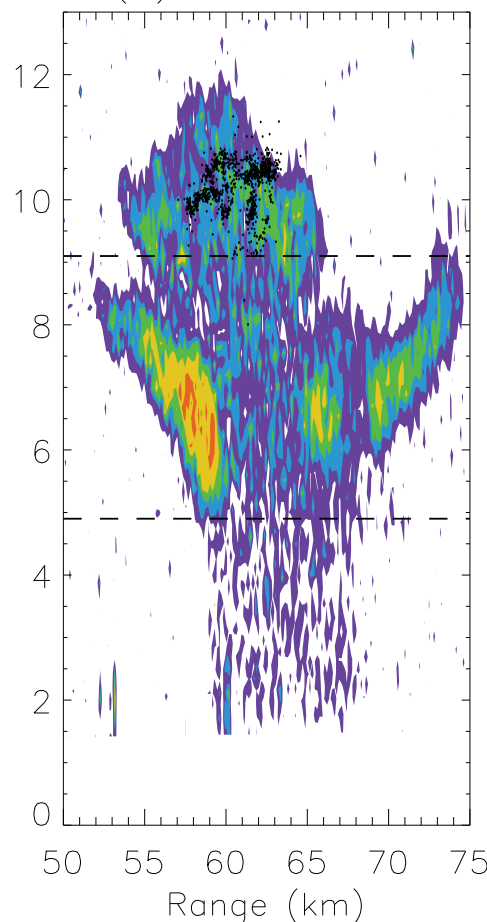
$Z_H$   
(a) Reflectivity



$Z_{DR}$   
(b) ZDR



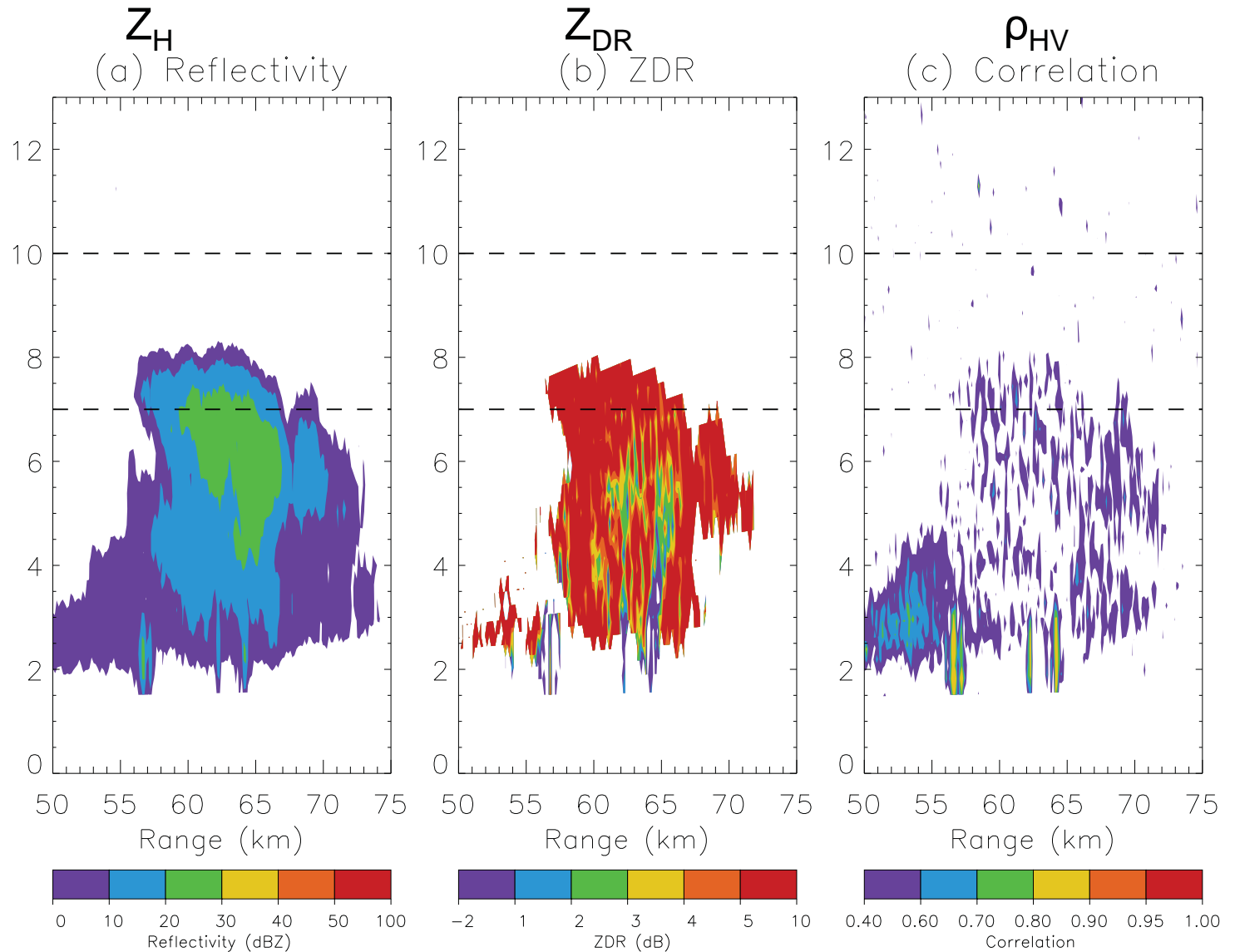
$\rho_{HV}$   
(c) Correlation



- Below LCL – High  $Z_{DR}$ /low  $\rho_{HV}$  indicating mostly smoke
- Above LCL – increasing  $\rho_{HV}$  and decreasing  $Z_{DR}$  – condensation/freezing?
- Mid-level cloud bookending plume – Low  $Z_{DR}$ /high  $\rho_{HV}$  relatively clean
- Near and above -40 °C altitude – ZDR -1 to +1 dB,  $\rho_{HV}$  ~0.6 or more
- Lightning occurred in this inferred ice/ash mixture

**Null Case**  
High Park Fire  
22 June 2012  
CHILL RHI  
(1956 UTC)

-40 °C →  
LCL →  
Height (km) MSL



- What about non-lightning-producing plumes?
- Many examples during DC3!
- Only smoke signature evident in polarimetric data
- No growth above -40 °C

# Motivation

- The lightning and microphysical structures observed in Colorado during 2012 are very unusual for thunderstorms. Are these observations seen in PyroCu elsewhere?
- The NEXRAD radar network was recently upgraded to dual-pol. Can we document the internal microphysical structures of PyroCu elsewhere?
- The 2012 PyroCu produced no NLDN-detected flashes. The NLDN was upgraded after 2012; can it now observe at least some PyroCu lightning?
- GOES-R will be launched soon and will feature the Geostationary Lightning Mapper (GLM) instrument. Can we expect GLM to provide useful information about PyroCu lightning?

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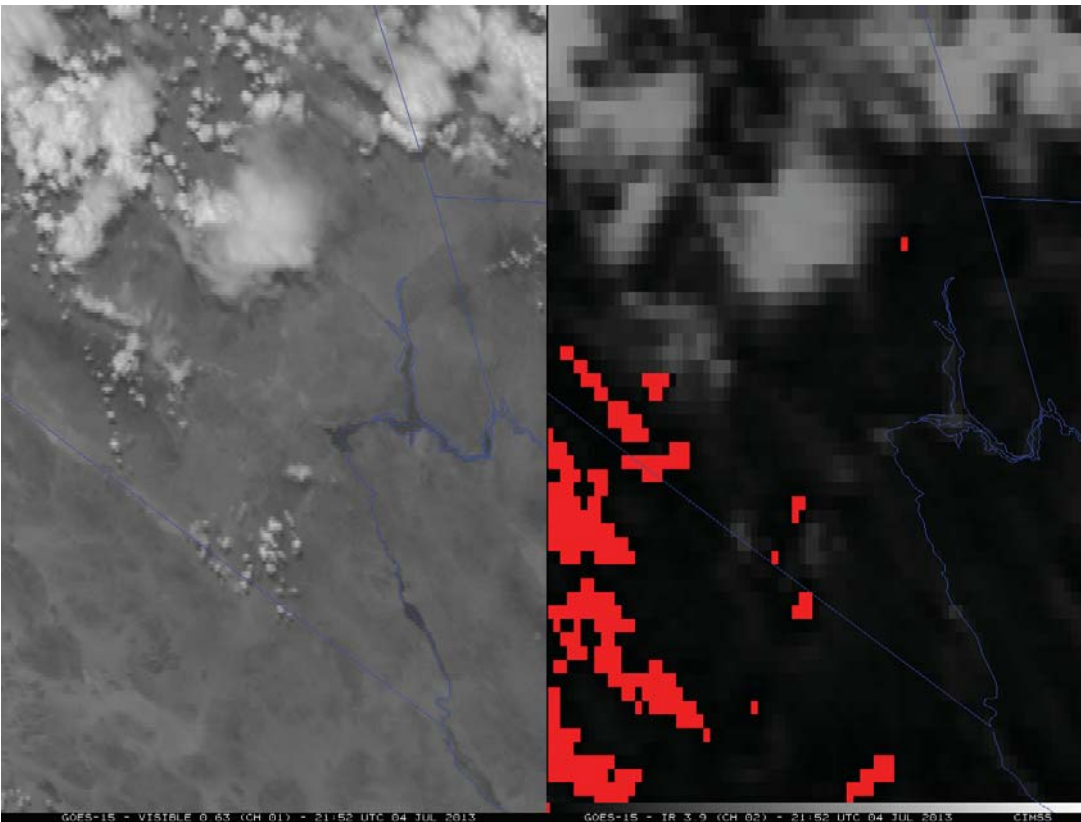
3. Geostationary Lightning Mapper (GLM) Proxy Data

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## Carpenter 1

GOES Visible and Shortwave IR  
4-5 July 2013 (~2200-0200 UTC)  
(Source: pyrocb.ssec.wisc.edu)

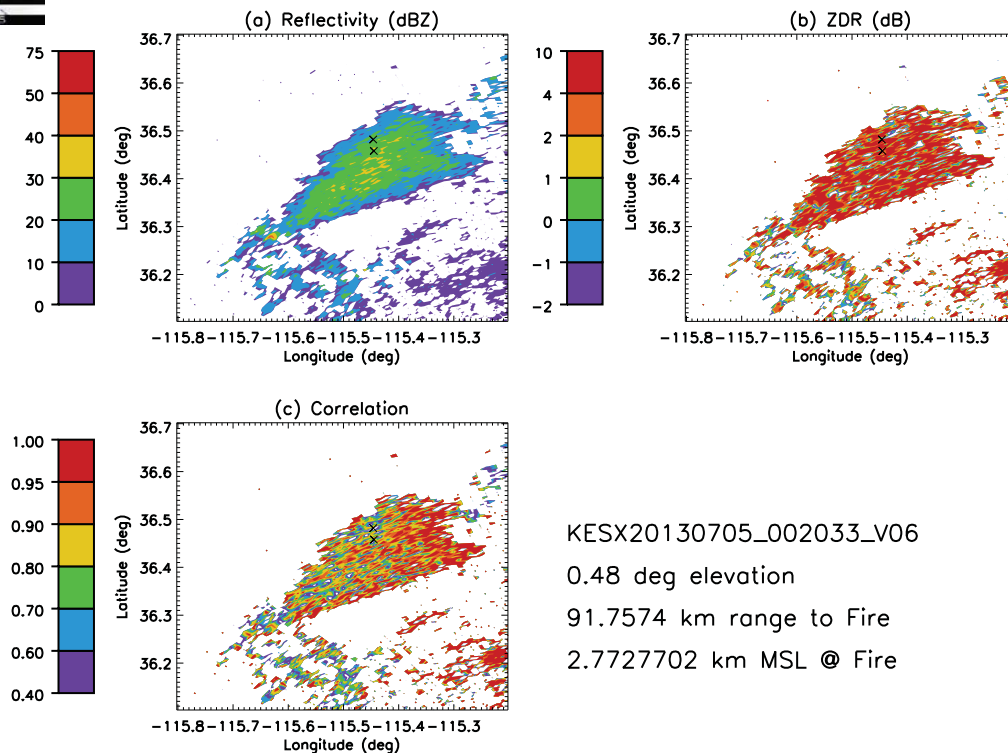


Las Vegas polarimetric NEXRAD  
0.5° sweep

0020 UTC, 5 July 2013

NLDN IC @ 00:23:20 UTC,  $I_{pk} = +4.5$  kA

NLDN IC @ 00:25:16 UTC,  $I_{pk} = +7.6$  kA



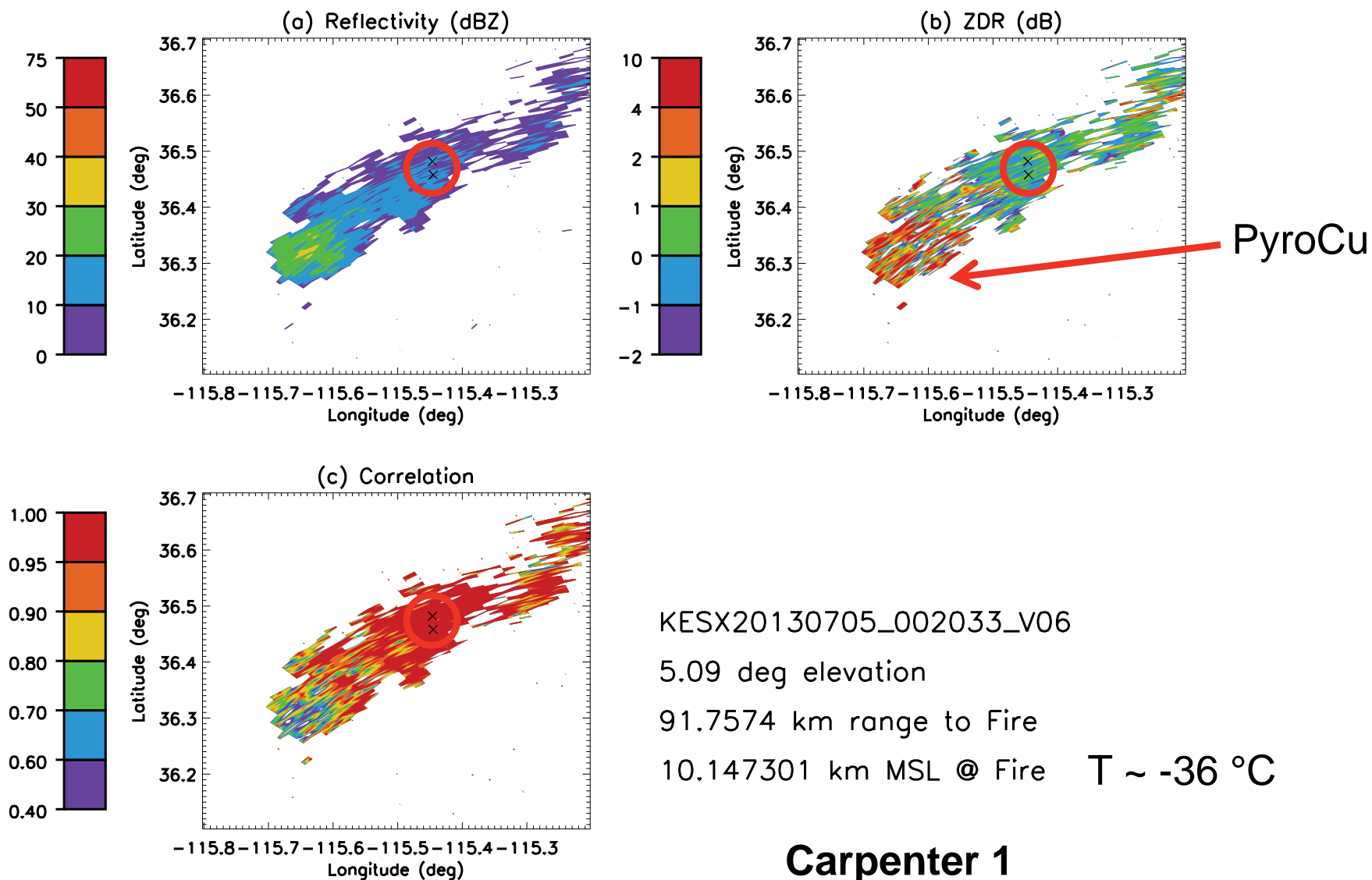
KESX20130705\_002033\_V06

0.48 deg elevation

91.7574 km range to Fire

2.7727702 km MSL @ Fire





Similar results for other 2013 incidents – West Fork (CO), Rim (CA), Silver (NM), Yarnell Hill (AZ)

## Carpenter 1

Las Vegas polarimetric NEXRAD

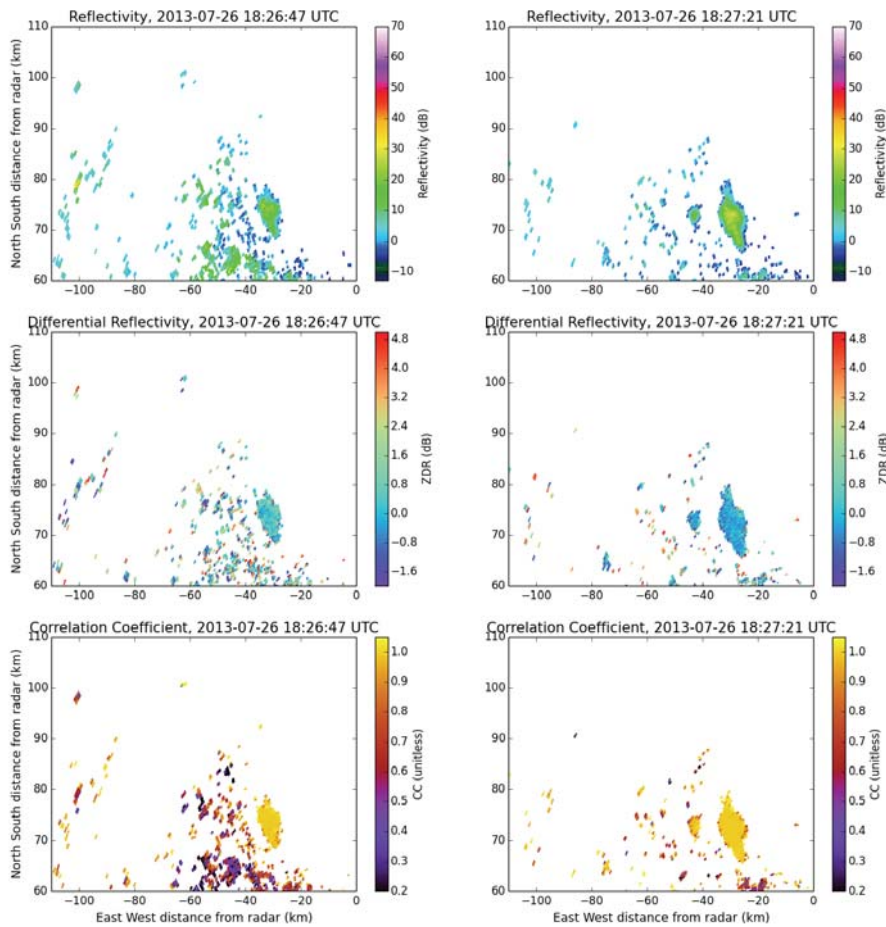
5.1° sweep

0020 UTC, 5 July 2013

NLDN IC @ 00:23:20 UTC,  $I_{pk} = +4.5$  kA

NLDN IC @ 00:25:16 UTC,  $I_{pk} = +7.6$  kA

KRIW 26-07-2013



$Z_H$

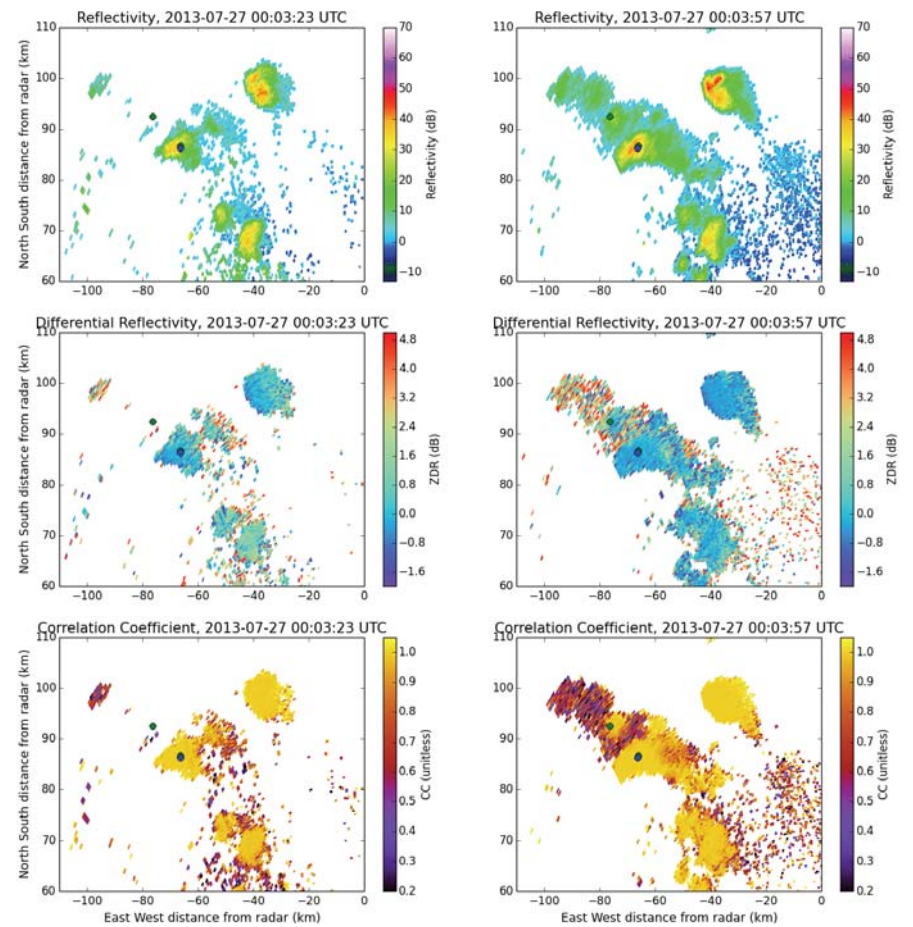
$Z_{DR}$

$\rho_{HV}$

Low Elevation Scan

Higher Elevation Scan

KRIW 27-07-2013

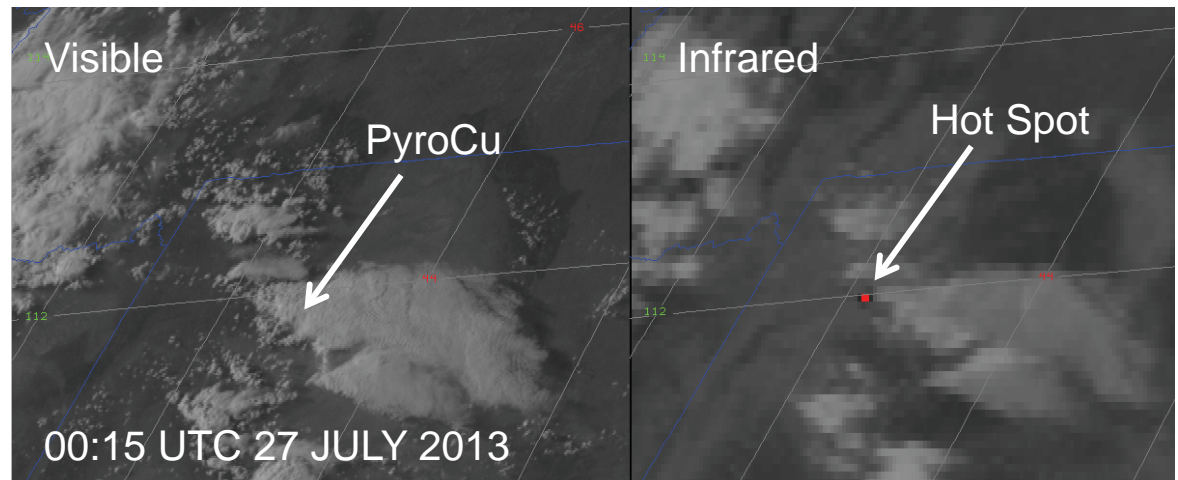


Low Elevation Scan

Higher Elevation Scan

## Hardluck Fire (Wyoming)

- Pyrocumulus development and lightning during 26-27 July 2013



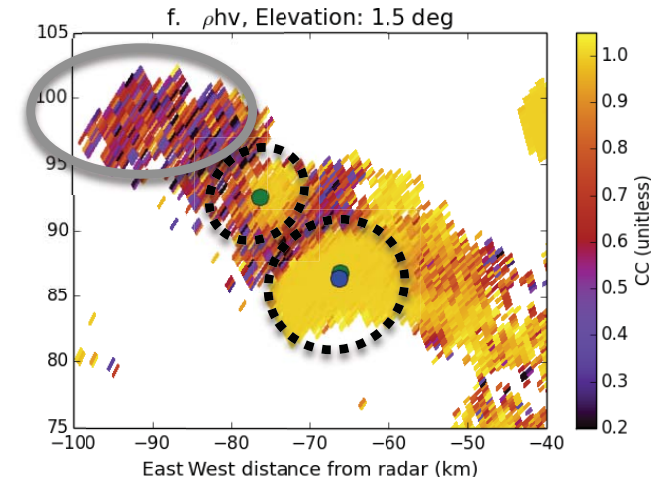
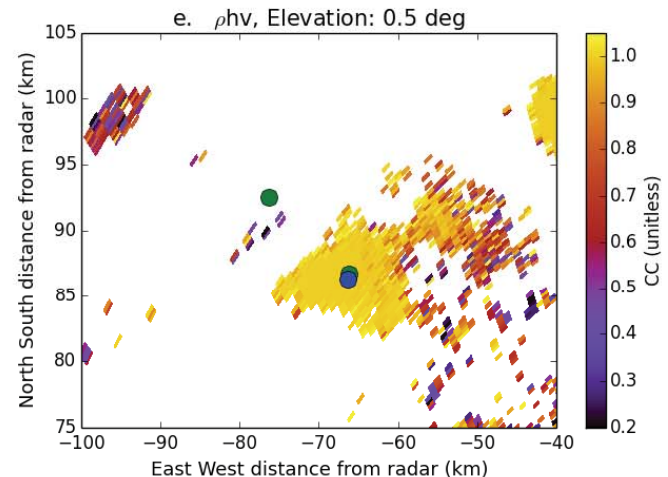
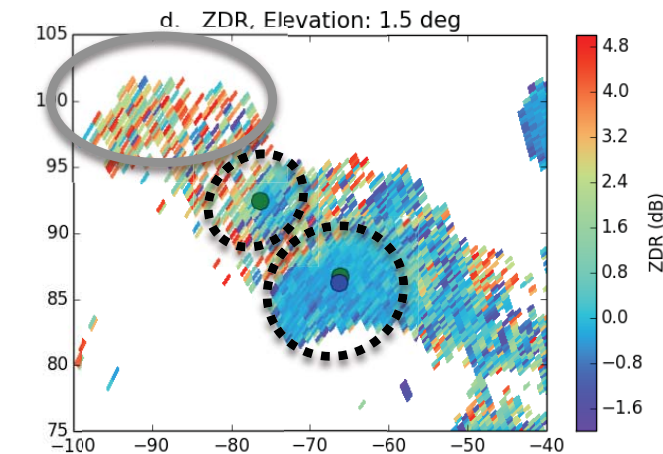
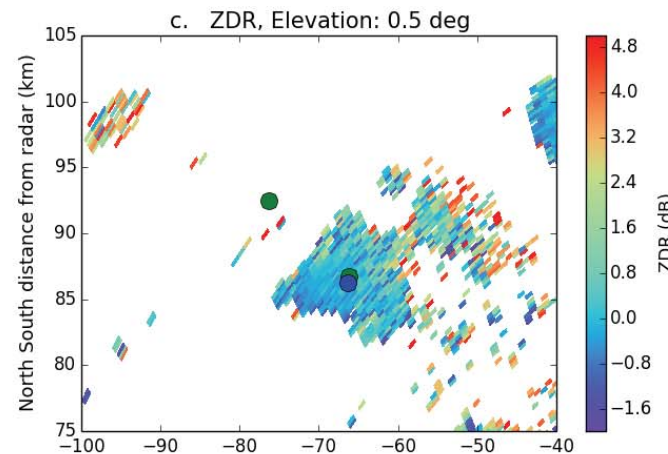
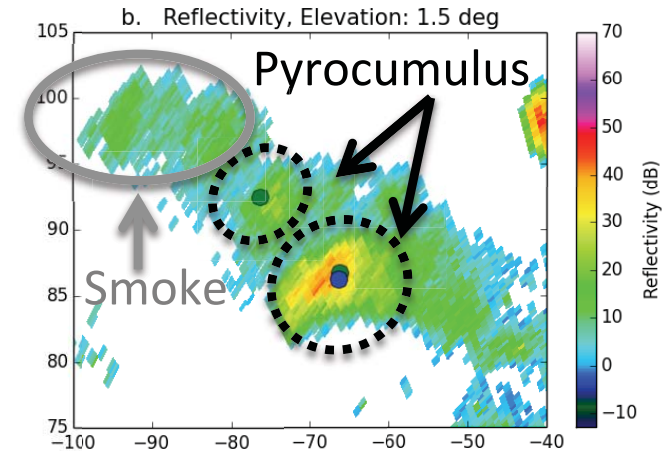
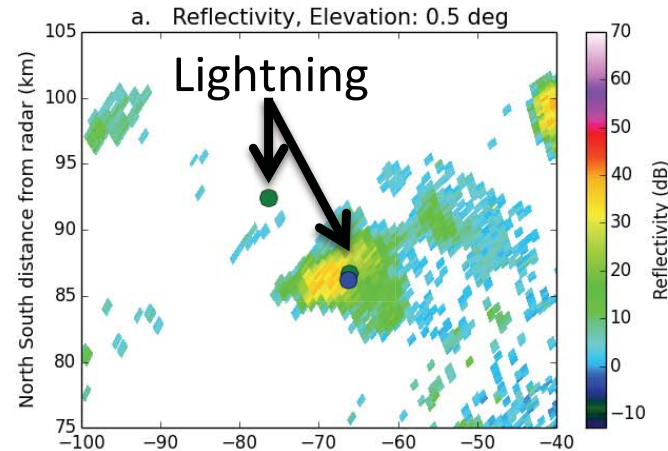
## Low Elevation Scan

● NLDN IC ● NLDN -CG ● NLDN +CG

## Higher Elevation

## Radar Values in Hardluck Pyrocumulus

- $Z_H$ : 15 to ~40 dBZ
- $Z_{DR}$ : 0.5 to -0.5 dB
- $\rho_{HV}$ : 0.7-1.0 (unitless)
- Indicates ice particles
- Pyrocumulus echo-top height: ~8.0 km
- 18 NLDN lightning flashes in 151 minutes

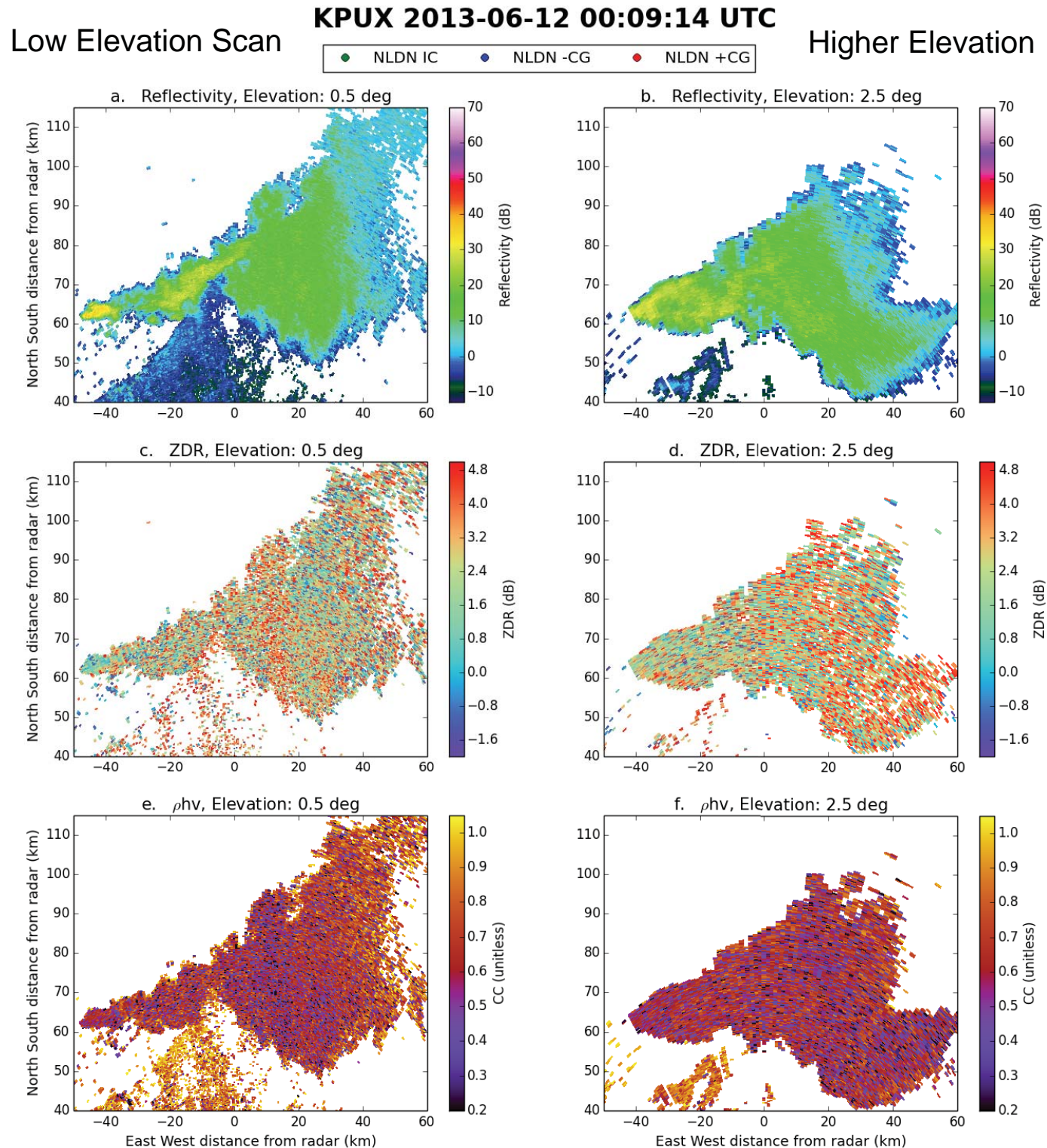




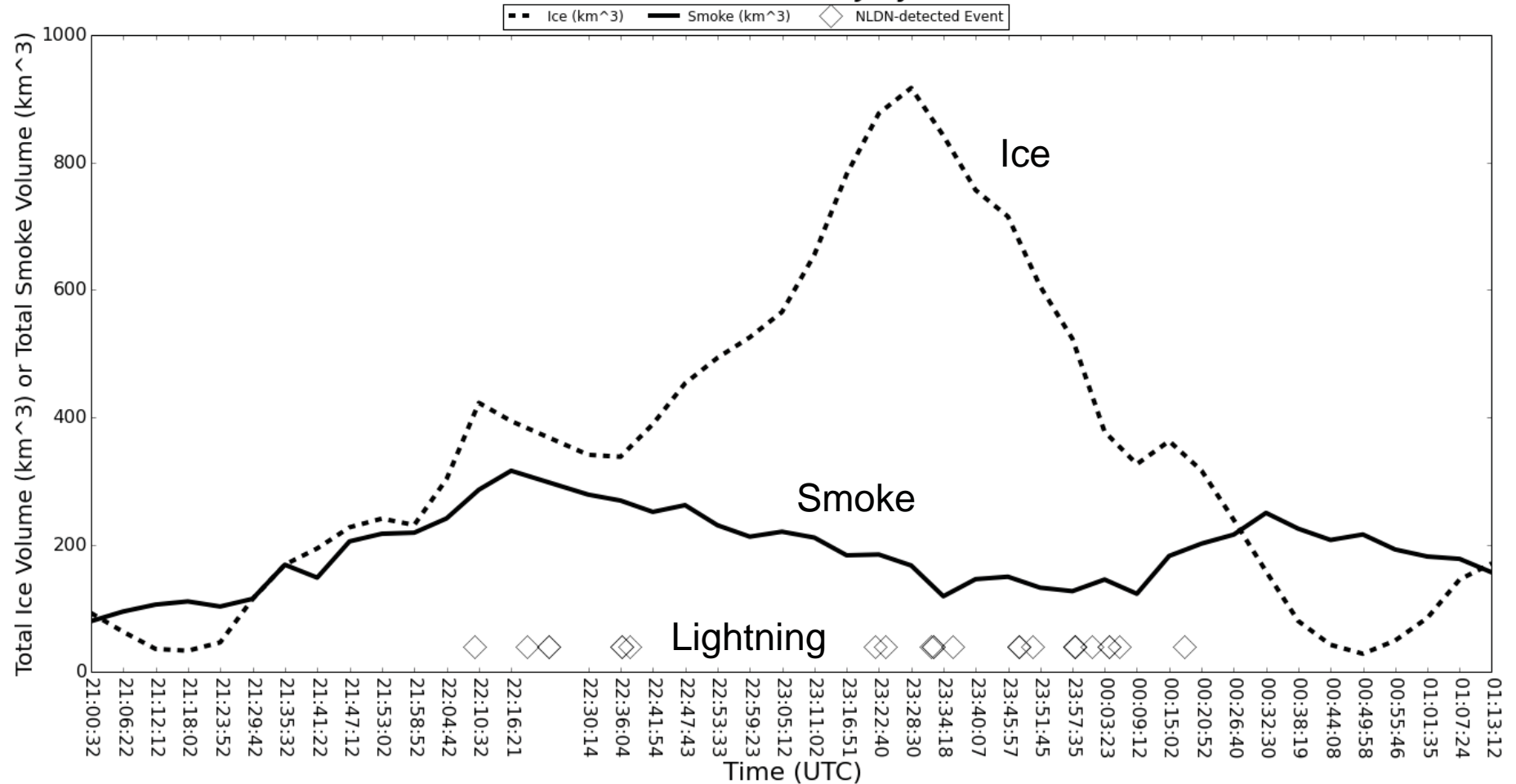
# Null Case

## Radar Values in Black Forest Smoke Plume

- $Z_H$ : 0 to ~30 dBZ
- $Z_{DR}$ : 1-5 dB
- $\rho_{HV}$ : 0.7 or less
- Indicates smoke particles
- Plume echo-top height: ~5.0 km
- No NLDN lightning



## Hardluck Fire 26-27 July 2013



**Table 1. List of radar parameter values used for determining if the radar was detection ice or smoke (from Lang et al. 2014)**

	Parameter	Parameter Minimum Value	Parameter Maximum Value
Ice	Reflectivity (dBZ)	$\geq 20$	$< 70$
	ZDR (dB)	$\geq -1$	$\leq 1$
	$\rho$ HV	$\geq 0.7$	$\leq 1.0$
Smoke	Reflectivity (dBZ)	$\geq 0$	$< 30$
	ZDR (dB)	$> 1$	$\leq 5$
	$\rho$ HV	$\geq 0$	$< 0.7$

### Simple particle identification

- Ice vs. Smoke
- Ice development leads occurrence of lightning

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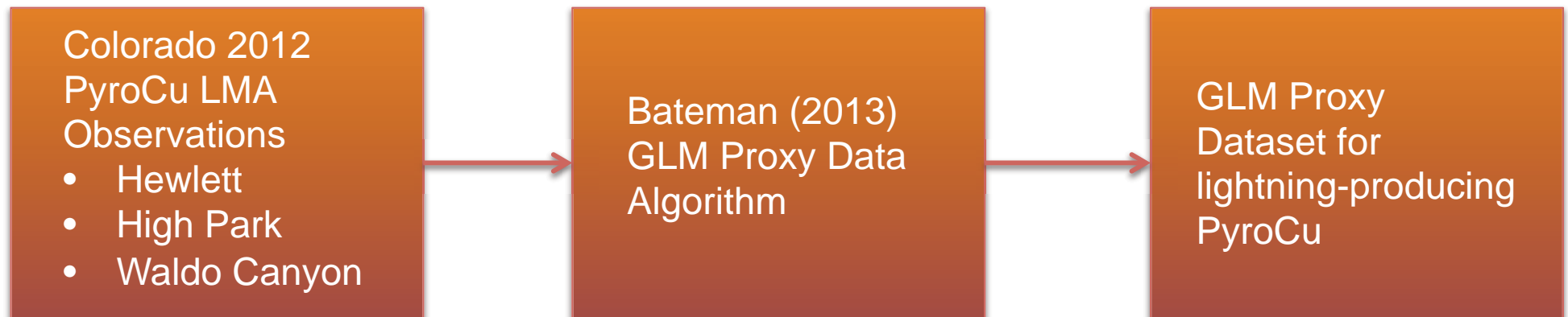
# Geostationary Lightning Mapper Proxy Data

## Motivation

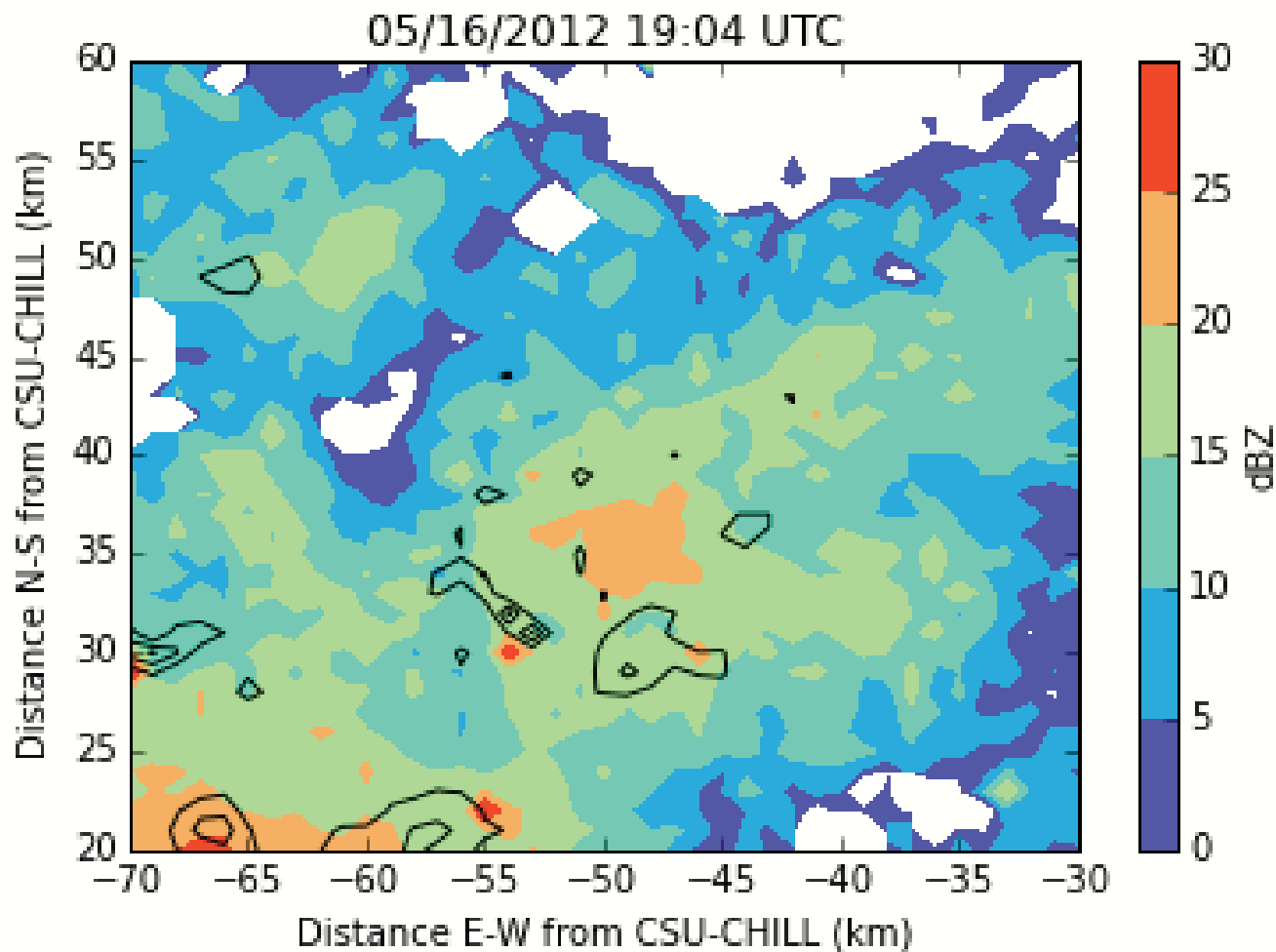
- Many of these PyroCu flashes are small, low-current ICs
- Will GLM be able to provide information about them?

## Method

- GLM proxy data were created using algorithms developed at MSFC (Bateman 2013)
- Algorithms based on statistical comparison of LMA and Lightning Imaging Sensor (LIS) observations of same lightning
- Proxy optical events clustered into proxy flashes
- Applied to Lang et al. (2014) LMA-mapped PyroCu lightning dataset







Magenta Stars  
GLM Proxy Flashes

Black Contours  
1 m s<sup>-1</sup> updraft

## Hewlett Fire Lightning

5/16 1948-2005 UTC

- LMA = 20 Flashes (10+ sources)
- GLM Proxy = 21 Flashes

### GLM Proxy Statistics

(Min, Median, Max)

**Footprint (km<sup>2</sup>)**

98.2, 294.4, 786.5

**Events per Flash**

1, 3.0, 15

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# Summary and Conclusions

- Ten additional case PyroCu studies (lightning and non-lightning) examined
- The novel 2012 pyrocumulus lightning observations described in Lang et al. (2014) were not an exception!
  - Vertical growth of cloud leads to development of precipitation-sized ice signature in polarimetric radar data, distinctive from smoke signature
    - Modest to high  $Z_H$ , noisy but near-0  $Z_{DR}$ , improved correlation
    - Presence of ice associated with occurrence of lightning
    - No ice signature, no lightning!
- Higher-sensitivity NLDN detects at least some of the weak ICs
- GLM appears capable of detecting even the small ICs
- Pyrocumulus development and lightning associated with significant fire growth

Dual-Pol NEXRAD + GOES-R/GLM + Upgraded NLDN =  
**Nationwide Pyrocumulus Electrification Observing Network**